AD-A111 284 CORPS OF ENGINEERS WALLA WALLA WA WALLA WALLA DISTRICT F/G 13/2
A CONCEPTUAL PLAN FOR MITIGATING ANADROMOUS FISH LOSSES IN THE --ETC(U)
OCT 80

UNCLASSIFIED NL

1 OF 1
AD A
111284

END
DATE
FILMED
03-82
DTIC

A CONCEPTUAL PLAN FOR MITIGATING ANADROMOUS FISH LOSSES IN THE HANFORD REACH COLUMBIA RIVER, WASHINGTON

PREPARED FOR U.S. ARMY CORPS OF ENGINEERS

SEATTLE DISTRICT

United States Army
Corps of Engineers
...Serving the Army
...Serving the Nation

Walla Walla District

1980

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

REPORT DOCUMENTATION PAGE

READ INSTRUCTIONS BEFORE COMPLETING FORM

1. REPORT NUMBER	2. GOVT ACCESSION NO. A? - A???	3. RECIPIENT'S CATALOG NUMBER 2??
4. TITLE (and Subtitle) A conceptual plan for mitigating anadromous fish losses in the Hanford Reach, Columbia River, Washington		5. TYPE OF REPORT & PERIOD COVERED
		6. PERFORMING ORG. REPORT NUMBER
7. AUTHOR(s)		8. CONTRACT OR GRANT NUMBER(s)
9. PERFORMING ORGANIZATION NAME AND ADDRESS Walla Walla District U.S. Army Corps of Engineers Walla Walla, WA 99362		10. PROGRAM ELEMENT, PROJECT, TASK AREA & WORK UNIT NUMBERS
11. CONTROLLING OFFICE NAME AND ADDRESS Seattle District US Army Corps of Engineers P.O. Box C-3755 Seattle, WA 98124		12. REPORT DATE October 1980
		13. NUMBER OF PAGES 45
14. MONITORING AGENCY NAME & ADDRESS (if different from Controlling Office)		15. SECURITY CLASS. (of this report) Unclassified
		15a. DECLASSIFICATION DOWNGRADING SCHEDULE

16. DISTRIBUTION STATEMENT (of this Report)

Approved for public release; distribution unlimited.

17. DISTRIBUTION STATEMENT (of the abstract entered in Block 20, if different from Report)

18. SUPPLEMENTARY NOTES

19. KEY WORDS (Continue on reverse side if necessary and identify by block number)

HANFORD REACH
COLUMBIA RIVER
WASHINGTON (STATE)
BEN FRANKLIN DAM
ANADROMOUS FISH
ENVIRONMENTAL IMPACT

20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

This report presents a conceptual plan for mitigating anadromous fish losses for the Ben Franklin Dam alternative and evaluates the realistic potential of such a plan. Major findings were:

The approach selected to achieve mitigation was to subdivide the production requirements into four hatcheries with regard to compatible production cycles and manageable size. A single, large facility was not considered

DD FORM 1 JAN 73 1473 EDITION OF 1 NOV 65 IS OBSOLETE

SECURITY CLASSIFICATION OF THIS PAGE (When Data Entered)

practical due to the water quantity requirement, conflicting production cycles of the fishes involved, and the increased potential for waterborne disease or environmental problems to eliminate an entire year class of fish at a facility supplied with a single water source.

Capital costs for the total mitigation hatchery plan (four hatcheries) were estimated at $39.1 million. Annual operation and maintenance costs (excluding energy) would be approximately $768,500.

The Mid-Columbia Public Utility Districts have developed a plan to substantially increase production at the Priest Rapids rearing facility in the future. A portion of the Ben Franklin mitigation requirement could theoretically be achieved using the expanded Priest Rapids facilities. The proposed expansion, however, is dependent upon the development of a substantial ground water supply. Availability of the requisite supply was not determined in this study and the expansion of the facility to mitigate losses from the Ben Franklin Dam alternative was not pursued. There are no other hatchery facilities in the area which are suitable for incorporation into the program.

Using a two-year cycle production cycle, the mitigation goal for steelhead could be met at hatcheries supplied with ambient Columbia River water. Siting would depend only upon the availability of suitable land.

Ground water sources were not confirmed in the study area. Without a ground water supply, the full mitigation goal for the salmon species could be met only if mechanical heating and cooling were employed to modify ambient Columbia River water temperatures. With single-pass water use, annual energy requirements for thermally modifying water to supply hatcheries producing spring, summer, and fall Chinook and coho would be approximately 308,000,000,000 BTU.

The necessary data upon which to construct a production model and base a facility design for sockeye salmon are not available. Until adequate data are developed, efforts should be directed at augmenting natural production in Lake Wenatchee on the Wenatchee River and Lake Osoyoos on the Okanogan River to ameliorate losses from the Ben Franklin Dam alternative.

A CONCEPTUAL PLAN
FOR MITIGATING ANADROMOUS FISH LOSSES
IN THE HANFORD REACH
COLUMBIA RIVER, WASHINGTON

PREPARED FOR U.S. ARMY CORPS OF ENGINEERS

SEATTLE DISTRICT

A

U.S. ARMY CORPS OF ENGINEERS
WALLA WALLA DISTRICT
OCTOBER 1980

A CONCEPTUAL PLAN
FOR MITIGATING ANADROMOUS FISH LOSSES
IN THE HANFORD REACH
COLUMBIA RIVER, WASHINGTON

TABLE OF CONTENTS

EXECUTIVE SUMMARY

This report presents a conceptual plan for mitigating anadromous fish losses for the Ben Franklin Dam alternative and evaluates the realistic potential of such a plan. Major findings were:

The approach selected to achieve mitigation was to subdivide the production requirements into four hatcheries with regard to compatible production cycles and manageable size. A single, large facility was not considered practical due to the water quantity requirement, conflicting production cycles of the fishes involved, and the increased potential for waterborne disease or environmental problems to eliminate an entire year class of fish at a facility supplied with a single water source.

Capital costs for the total mitigation hatchery plan (four hatcheries) were estimated at $39.1 million. Annual operation and maintenance costs (excluding energy) would be approximately $768,500.

The Mid-Columbia Public Utility Districts have developed a plan to substantially increase production at the Priest Rapids rearing facility in the future. A portion of the Ben Franklin mitigation requirement could theoretically be achieved using the expanded Priest Rapids facilities. The proposed expansion, however, is dependent upon the development of a substantial groundwater supply. Availability of the requisite supply was not determined in this study and the expansion of the facility to mitigate losses from the Ben Franklin Dam alternative was not pursued. There are no other hatchery facilities in the area which are suitable for incorporation into the program.

Using a two-year production cycle, the mitigation goal for steelhead could be met at hatcheries supplied with ambient Columbia River water. Siting would depend only upon the availability of suitable land.

Groundwater sources were not confirmed in the study area. Without a groundwater supply, the full mitigation goal for the salmon species could be met only if mechanical heating and cooling were employed to modify ambient Columbia River water temperatures. With single-pass water use, annual energy requirements for thermally modifying water to supply hatcheries producing spring, summer, and fall Chinook and coho would be approximately 308,000,000,000 BTU.

The necessary data upon which to construct a production model and base a facility design for sockeye salmon are not available. Until adequate data are developed, efforts should be directed at augmenting natural production in Lake Wenatchee on the Wenatchee River and Lake Osoyoos on the Okanogan River to ameliorate losses from the Ben Franklin Dam alternative.

FIGURES

TABLES

INTRODUCTION

Should the Ben Franklin Dam alternative be constructed on the Hanford Reach of the Columbia River, Washington, a major habitat modification with consequent anadromous fish losses will occur. This report presents a conceptual anadromous fish mitigation plan based on losses identified in "Aquatic and Riparian Resource Study of the Hanford Reach, Columbia River, Washington" by Fickeisen et al, 1980.

Construction of conventional fish hatcheries was considered to be the primary means of achieving mitigation. General policies and constraints, upon which siting and design considerations were based, were developed with regard to previous mitigation efforts by the Corps and other agencies, a review of relevant literature and the existing data base. Water quality and quantity requirements, rearing schedules, capacities, and types and dimensions of facilities, were based on requirements of individual species and criteria established by interested state and Federal agencies.

The area of consideration for potential mitigation hatchery siting was limited to the Columbia River drainage from the Snake-Columbia confluence to Priest Rapids Dam (Figure 1). Temperature was considered to be the most critical parameter affecting hatchery operation, and potential sites were evaluated primarily on the temperature regime of their water supply, using currently available water quality information.

This study was preliminary in scope. Facilities were designed with conventional single-pass water use. Selection of potential hatchery sites was limited by the lack of groundwater information. Not all aspects of combined facility usage, integrated programs, or detailed modifications for individual facilities were addressed. Incorporation of hatchery technology more appropriate to the region, and more detailed groundwater investigations could affect the conclusions.

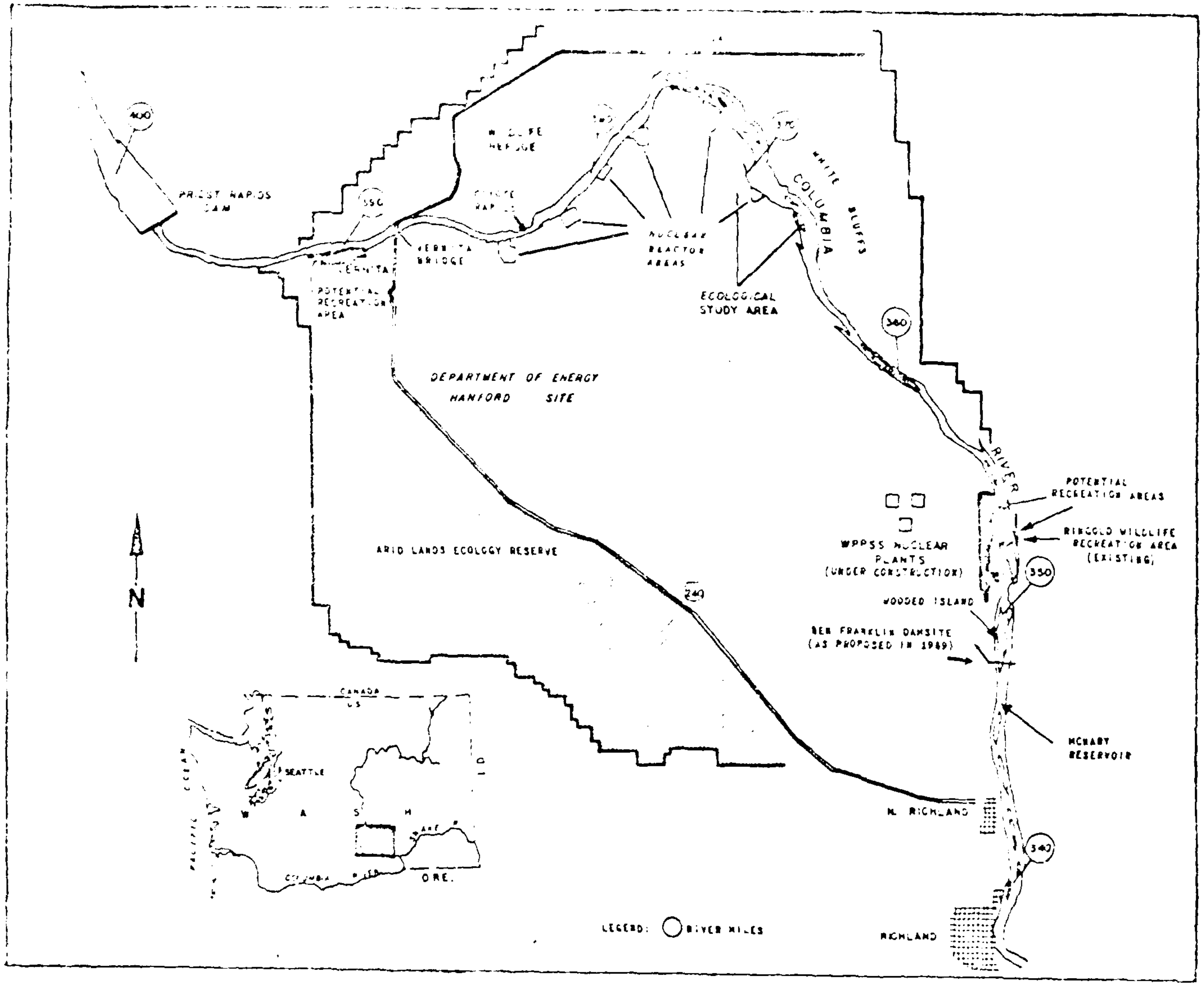


Figure 1. Study area - Hanford Reach of the Columbia River, Washington.

PRODUCTION STRATEGIES

Mitigation requirements and production models (Table 1) were based on potential anadromous fish losses from the Ben Franklin Dam alternative presented in "Aquatic and Riparian Resource Study of the Hanford Reach, Columbia River, Washington," by Fickeisen et al, 1980. Production strategies for mitigating individual species losses are as follows:

1. Steelhead Rainbow Trout (*Salmo gairdneri*)

Facilities capable of annually producing 225,000 pounds of 8 fish/lb. steelhead smolts (1.8 million individuals) would be required to compensate for: (1) loss of natural production in the Hanford Reach due to loss of habitat (up to 1.6 million smolts), (2) loss of hatchery production due to inundation of the Ringold rearing facility (160,000 smolts), and (3) losses of smolts produced above Priest Rapids during downstream passage through the Ben Franklin Dam and impoundment (estimated at 60,000 to 100,000 smolts lost due to migration delays, spill, and turbine mortalities).

The growth of artificially propagated salmonids may be manipulated (temperature control, feeding rates, etc.) to have fish at a predetermined optimum size at the onset of smoltification. Releases of smolts which are larger or smaller than this optimum generally result in reduced survival and poor adult returns. Since growth rates are size-related and decrease with age, the amount of rearing schedule manipulation that can be accomplished depends upon release size and life history of the particular species. Steelhead, because of their larger release size (8 per lb. vs. 12.5, 90, and 27.5 for spring and summer Chinook, fall Chinook, and coho), and different hatching time (late spring vs. early winter for salmon species), may be adapted to a one- or two-year cycle.

TABLE 1

HATCHERY PRODUCTION MODELS FOR
MITIGATION OF ANADROMOUS FISH LOSSES
BEN FRANKLIN DAM ALTERNATIVE
(Data Selected From Columbia Basin Fisheries Technical Committee's
Lower Snake Hatchery Subcommittee Memorandum, 1974)

	Steelhead (2-year rearing)	Fall Chinook	Summer Chinook	Spring Chinook	Coho Salmon	Sockeye Salmon
Number of smolts required	1.8 million	5.3 million	598,000	128,000	228,000	240,000
Size at release (smolts/pound)	8	90	10-15	10-15	25-30	**
Pounds of smolts	225,000	58,889	47,840	10,240	8,291	12,000
Egg-smolt survival (%)	50	80	70	70		
Number of eggs required	3.6 million	6.63 million	854,286	182,857	325,714	**
Number of eggs per female	5,000	5,000	4,500	4,500	4,500	3,600
Number of females	720	1,325	190	41	72	**
Survival to spawning (%)	95	95	80	80	80	**
Number of adults required*	1,395	3,487	593	127	226	**

* Assuming a 60:40 male:female ratio for returning adults.
** Not established.

Considering the water quantity requirements, the temperature regime of surface waters, and the specific requirements of steelhead, one-year rearing could be accomplished successfully only if an adequate supply of cool (7.2 to 15.0°C) groundwater were available, or supplemental cooling and heating of surface water were provided. Two-year rearing, using surface water with groundwater supplementation or thermal modification during critical periods, was selected as a production strategy (Figure 2).

2. Chinook Salmon (Oncorhynchus tshawytscha)

a. Spring and Summer Chinook.

Mitigation requires an annual production of 47,840 pounds of summer Chinook smolts and 10,240 pounds of spring Chinook smolts (598,000 and 128,000 individuals, respectively) to replace the estimated loss to smolts produced above Priest Rapids Dam during downstream passage through Ben Franklin Dam impoundment. Facilities capable of collecting the required numbers of adults, successfully holding them, spawning and incubating eggs, and producing 10-15/lb. smolts during the 17- to 18-month rearing period would be necessary.

Except for the earlier upstream migration of spring Chinook adults (April vs. June), the life cycles and rearing requirements of spring and summer Chinook are similar (Figure 2). The early upstream migration of these races and consequent extended adult holding period imposes difficult problems in maintaining the health of the spawners. To prevent excessive losses, adult holding ponds should be supplied with cool (less than 13.3°C) water. In view of the temperature regime of surface water in the region, this condition could be met only if supplemental cooling were provided or facilities were restricted to areas where groundwater supplies are available.

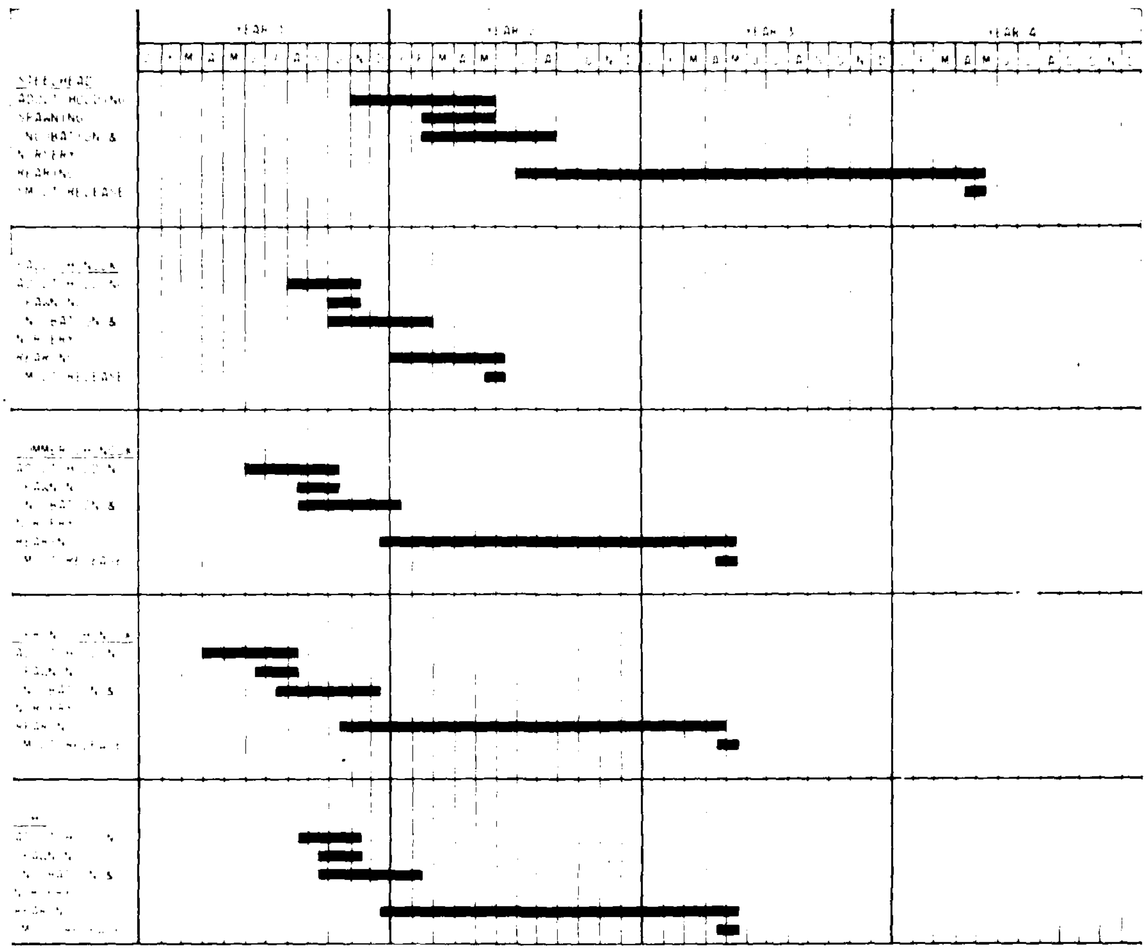


FIGURE 2 HATCHERY PRODUCTION SCHEDULES FOR STEELHEAD CHINOOK SALMON AND COHO SALMON (FROM BELL 1973)

b. Fall Chinook.

Losses of fall Chinook salmon would include lost production of naturally spawning fish in the Hanford Reach due to destruction of suitable habitat (1.4 million smolts per year). In addition, the artificial production at Ringold would be lost due to inundation of the facility, which produces about 1 to 2 million smolts per year. The production at Priest Rapids would also be lost because of loss of the spawning stock, representing an additional 1.9-million juveniles annually. Thus the total loss for fall Chinook salmon is estimated at 4.3 to 5.3 million smolts per year.

Although the fall Chinook mitigation goal represents the largest individual requirement (5.3 million smolts), their abbreviated hatchery cycle (egg-to-smolt in 6-8 months) and small release size makes their production criteria relatively simple when compared to requirements for other fish. Fish are not held during the time of year when high temperatures are a problem, and hatcheries could presumably rely on surface water supplies to a greater extent than those for other fish. Winter surface-water temperatures in the region are generally too cold for optimum production, and a water supply system which balances ambient temperatures with supplemental heating or warmer groundwater would be necessary.

3. Coho Salmon (Oncorhynchus kisutch)

The hatchery production cycle of coho salmon is similar to that of spring and summer Chinook (Figure 2) and, except for a shorter adult holding time, would be subject to the same requirements and constraints. The mitigation goal is an annual production of 8,291 pounds of 25-30/lb. smolts and would require a 16-month rearing cycle. Mitigation would be required for the estimated 228,000 smolts lost annually during downstream passage through the Ben Franklin Dam impoundment.

4. Sockeye Salmon (Oncorhynchus nerka)

An estimated 1.6 million sockeye salmon smolts pass through the Hanford Reach annually. It is expected that up to 240,000 of these smolts would be lost due to the Ben Franklin Dam alternative. Because of their requirement for a "nursery" lake in which to grow and their susceptibility to viral diseases when intensively cultured (Wood, 1974), sockeye salmon are not especially suited to conventional hatchery production. Since termination of the sockeye program at Leavenworth National Fish Hatchery on the upper Columbia in 1967, there have been no attempts to raise sockeye in hatchery facilities in the entire Columbia Basin (Wahle and Smith, 1979). The only sockeye propagation facility in the State of Washington is located on the Cedar River (a tributary of Lake Washington) and involves incubation of eggs in boxes placed in the stream with fry outmigrating into the lake as they emerge from the gravel (Washington State Department of Fisheries, 1980). There are no fry-to-smolt survival data available at this time and it is therefore not possible to construct a sockeye salmon production model and establish numerical requirements upon which to base a facility design. Until adequate data from the Cedar River project are developed, efforts should be directed at augmenting natural production in Lake Wenatchee on the Wenatchee River and Lake Osoyoos on the Okanogan River to ameliorate losses from the Ben Franklin Dam alternative.

WATER QUALITY REQUIREMENTS

A water source for a salmonid hatchery facility must meet specific temperature criteria, be free from toxic substances and pathogenic organisms, and conform to basic requirements for dissolved oxygen, pH, and alkalinity. With the generally good surface-water quality in the region, temperature is the most critical parameter in determining the suitability of any particular water source.

Although various authors differ on the specific limits, it is agreed that each species of fish has a characteristic optimum and tolerance range of temperature for rearing, spawning, and egg incubation (Table 2). Optimum rearing temperatures and ranges at which all physiological systems are operating efficiently have been defined as: steelhead rainbow trout, 11.1°C (7.2-15.0); coho salmon, 13.0 (11.6-14.4); Chinook salmon (all races) 10.8°C (7.2-14.4); and sockeye salmon, 12.7°C (11.1-15.0). Temperatures outside these ranges are tolerated, but any deviation from the optimum causes decreased growth rates and increased susceptibility to diseases.

Spawning and egg incubation require lower temperatures. Egg development in Chinook salmon and steelhead spawners is adversely affected if fish are held at water temperatures exceeding 13.3°C (Leitritz and Lewis, 1976). The literature is not as specific on the upper temperature limits for coho and sockeye spawners. Their preferred spawning temperatures, however (4.4-9.4°C and 10.5-12.2°C, respectively), are in the same general range as those of steelhead and Chinook (Bell, 1973), and it is assumed that temperatures above 13.3°C would also adversely affect their egg development.

The incubation period for eggs varies with the species (and race) of fish and water temperature at which eggs are held. Temperatures between 5.5 and 13.3°C are considered necessary for normal development (Leitritz and Lewis, 1976).

TABLE 2

SUMMARY OF PREFERRED TEMPERATURES (IN DEGREES C)
FOR VARIOUS LIFE STAGES OF SOME SALMONIDS

(Data selected from Bell, 1973; Brett, et al., 1958; Leitritz and Lewis, 1976; Olsen and Foster, 1957.)

	Rearing	Spawning	Incubation
Chinook	7.2 - 14.4	5.5 - 13.3	5.5 - 13.3
Coho	11.6 - 14.4	4.4 - 9.4	5.5 - 13.3
Sockeye	11.1 - 15.0	10.5 - 12.2	5.5 - 13.3
Steelhead	7.2 - 15.0	3.9 - 13.3	5.5 - 13.3

DESIGN CRITERIA

Design criteria for fish hatcheries are an important consideration because they affect the amount of land required and the quantity of water necessary for operation. As illustrated in Figure 3, water use in a hatchery can be described as: (1) single-pass - through only one rearing unit and then discharged; (2) simple recirculation - water entering or leaving a rearing unit is subjected to a single process so that a reduced water supply can support the same level of fish population; and (3) complex recirculation - water flowing from the rearing ponds is subjected to two or more processes to further reduce the quantity of water required to support a given fish population. Although less practical in areas where the supply of suitable water is limited, hatcheries with single-pass systems have fewer disease problems than those in which water is re-used.

The State of Washington required that single-pass systems be used in hatchery facilities built under the Lower Snake River Compensation Plan (U.S. Army Corps of Engineers, 1980a). It is probable that this requirement would be applied to mitigate for the Ben Franklin Dam alternative and, accordingly, designs in this report are based on single use.

Criteria used in designing facilities and determining water quality requirements were based on requirements established in the hatchery production models (Table 1) and the specific cultural requirements of the various fishes.

An important difference in physical requirements among species of fish is density. A density index (DI) concept developed by Piper (1972) is based on the fact that each species of fish has an upper limit to which it may be crowded before growth and survival are adversely affected. Since hatchery construction costs are directly related to the

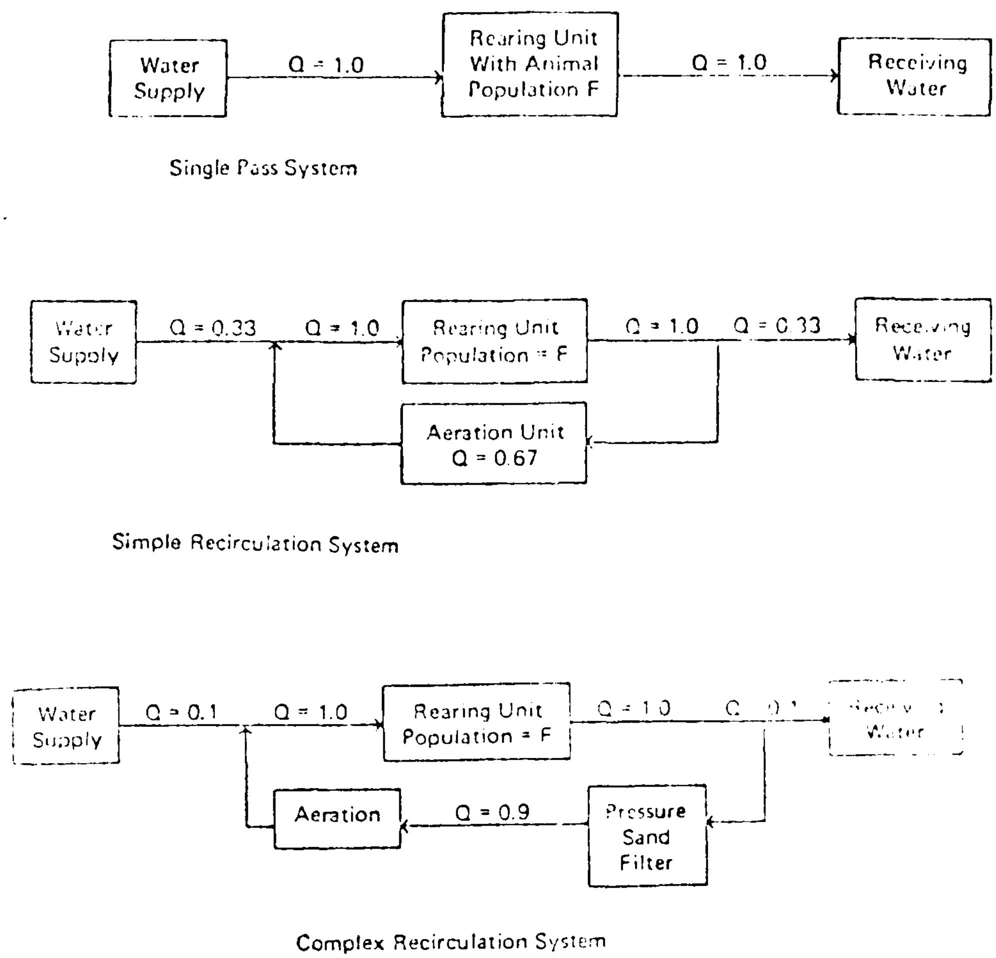


Figure 3. General representation of fish hatchery water use systems. Q represents water flow rate in arbitrary dimensionless units, and Q = 1.0 is the flow rate required to maintain a satisfactory oxygen level for the animals in the rearing unit. (From Mayo, 1980)

size of the facility, the density index concept is an important design consideration in assuring that optimum use is made of rearing space. The DI equals the pounds of fish per cubic foot per inch of body length. Maximum raceway loading rates were calculated using the following DI values:

Chinook Salmon	0.3
Coho Salmon	0.4
Steelhead	0.4

Steelhead are an anadromous race of the rainbow trout Salmo gairdneri and the DI used (0.4) was arbitrarily reduced from the 0.5 value recommended for rainbow. Although the calculated maximum loadings were somewhat higher than those of other steelhead rearing facilities (U.S. Army Corps of Engineers, 1980b), they were based on the same formula used to determine loadings for the other species, and were accepted as the basis for design of the steelhead facilities.

Once the maximum loading for each species had been established, the flow requirement was determined by applying Piper's (1970) Load Factor Method:

$$I = \frac{Wf}{F \times L} \qquad (1)$$

where: I = water inflow (gpm); W_f = total weight of fish in ponds (lbs.); L = length of fish (in.); and F = load factor of 1.34 lbs. of fish/gpm/in. (at average Hanford Reach elevation of 500 feet and expected water temperature at maximum loading of 14.4°C).

Adult anadromous salmonids are at various stages of sexual maturation when they arrive at a hatchery, and facilities must be provided so that they may be held until they are "ripe" for spawning. Eggs are usually hatched in vertical incubators having stacks of trays, each supplied with re-aerated flow from the tray above. Newly hatched fry may be reared in indoor troughs until they are large enough to move outside to raceways. Outdoor raceway rearing is continued until the fish reach the smolt stage. They are then released to begin their seaward migration. In two to five years, depending upon the species, a small percentage of these smolts returns to the hatchery as adults and continues the cycle.

Facilities were designed so that adults would be collected, held, and spawned; eggs incubated; fry reared to release size; and smolts released at each individual hatchery. The following component designs were selected as the basis for the mitigation hatcheries:

Adult Holding Ponds:

Type = Rectangular, concrete
Dimensions (ft.) = 100 x 10 x 4.5 - 5.25 (0.75% slope)
Water capacity (3 ft. deep)(cubic ft.) = 3,000
Flow per pond (cfs) = 1.0
Cubic feet per adult = 10.0

Incubation:

Type = Vertical flow tray units (16 trays per stack)
Egg capacity (per tray) = 10,000
Flow requirement per stack (gallons per minute) = 10.0

Starter Troughs:

Type = Rectangular, concrete

Dimensions (ft.) = 21 x 2.67 x 2

Water capacity (1.67 ft. deep)(cu.ft.) = 93.3

Flow per trough (gpm) = 50

Pounds of fish per gpm = 2.0

Pounds of fish per cubic feet = 1.0

Raceways:

Type = Rectangular, concrete

Dimensions (ft.) = 100 x 10 x 4.5 - 5.25 (0.75% slope)

Water capacity (4 ft. deep)(cu.ft.) = 4,000

Maximum loading (lbs. of fish per raceway):

Spring and summer Chinook	6,900
Fall Chinook	3,600
Coho	7,200
Steelhead	10,800

Flow per raceway (cfs):

Spring and summer Chinook	2.0
Fall Chinook	2.0
Coho	2.6
Steelhead	2.6

Pounds of fish per gpm:

Spring and summer Chinook	7.68
Fall Chinook	4.00
Coho	6.16
Steelhead	9.25

Pounds of fish per cubic foot:

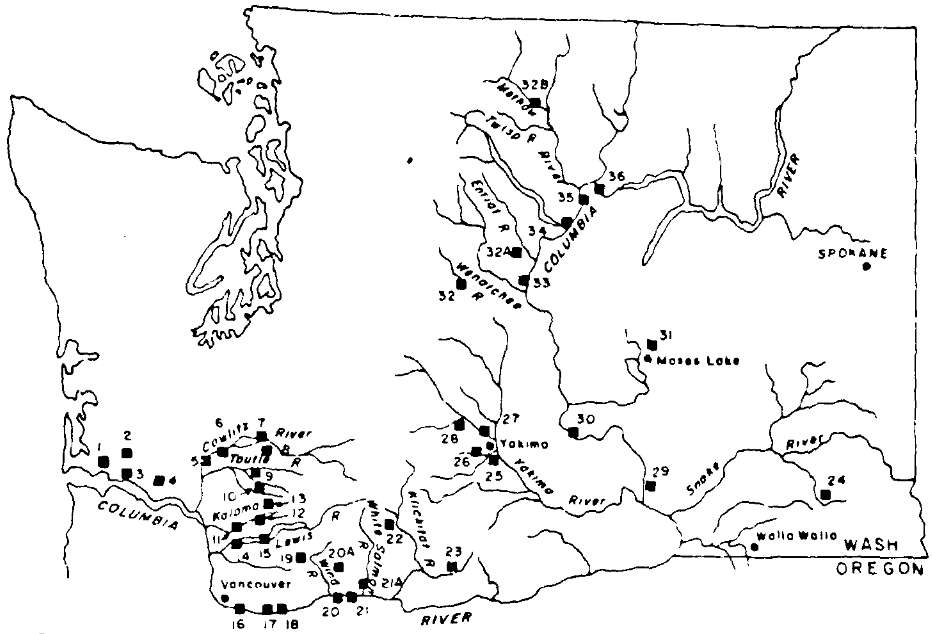
Spring and summer Chinook	1.72
Fall Chinook	0.9
Coho	1.8
Steelhead	2.7

MITIGATION HATCHERY PLAN

There are several approaches to presenting a plan capable of mitigating anadromous fish losses attributed to the construction of the Ben Franklin Dam alternative. A single large hatchery would require the construction and development of fewer supporting facilities (residences, water supply lines, power lines, etc.) and would be more cost effective. Aside from the problem of locating a suitable quantity of water, a major constraint to having a single-source water supply would be the potential for a waterborne disease to eliminate an entire year class of fish.

Another approach to be considered is the expansion of existing hatcheries to partially or entirely fulfill the mitigation requirement. There are several salmonid rearing facilities within the study area (Figure 4) but only one, Priest Rapids, would have the potential to be expanded to provide a portion of the Ben Franklin Dam alternative mitigation requirement. Since the low flows, diversions, and poor water quality in the lower reaches of the Yakima River restrict upstream migration of adults, expansion of facilities on the upper Yakima River (Yakima, Nelson Bridge Pond, Naches, and Nile Springs) would not be a feasible alternative. The Ringold facility would be inundated by the impoundment created by Ben Franklin Dam.

According to a proposed optimum management and development plan (Kaczynski and Moos, 1979), the production potential at the Priest Rapids facility could be expanded to more than three times the mitigation goal required by the Mid-Columbia Public Utility Districts. In theory, this would mean that the excess production capability (280,000 lbs. of smolts) could be made available to provide up to 80 percent of the mitigation requirement for the Ben Franklin Dam alternative. The success of this plan, however, is entirely dependent upon the development of a substantial groundwater supply, and, although excellent possibilities exist for the future, utilization of the proposed



Map No	Facility
1	Grays River
2	Elokomin
3	Beaver Creek
4	Abernathy
5	Cowlitz Trout
6	Cowlitz Salmon
7	Mossyrock
8	Swofford Pond
9	Toutle
10	Alder Creek Pond
11	Lower Kalama
12	Kalama Falls
13	Gobar Pond
14	Lewis River
15	Speelyai
16	Vancouver
17	Skamania
18	Washougal
19	Carson
20	Little White Salm..n
	20A Willard

Map No	Facility
21	Spring Creek
	21A Big White Salmon Pond
22	Klickitat
23	Goldendale
24	Tucannon
25	Nile Springs
26	Yakima
27	Nelson Bridge Pond
28	Naches
29	Ringold Trout
	Ringold Salmon
30	Priest Rapids
31	Columbia Basin
32	Leavenworth
	32A Entiat
	32B Winthrop
33	Rocky Reach
34	Chelan PUD
35	Wells Trout Hatchery
	Wells Salmon Pond
36	Washburn Island

N

0 80 160

Scale in Kilometers

Figure 4. Map of locations of Columbia Basin-Washington salmonid rearing facilities. (From Wahle and Smith, 1979)

production at Priest Rapids was not considered an acceptable mitigation alternative for the purposes of the present study.

Considering design and construction costs, land requirements, water quantity and quality requirements, manageable size, and life cycles of the fishes involved, the approach selected for the present plan involved subdividing the production of mitigation goals into four small hatcheries (Figures 5 to 8). Since the steelhead mitigation goal required the greatest quantity of water, and their hatchery production cycle and water quality requirements were different from the other species, hatcheries I and II were designated to provide the steelhead mitigation requirement. The fall Chinook salmon goal, which also represented a large water-quantity requirement, was divided between hatcheries III and IV. To make efficient use of personnel, equipment, and rearing space, a hatchery should have fish at some stage of development on hand at all times. With their abbreviated production cycle (egg-to-smolt in 6 to 8 months), fall Chinook are not especially suitable for a hatchery to rear as a single species, so the mitigation requirements for spring Chinook, summer Chinook, and coho were also divided between hatcheries III and IV.

Fish hatchery development and construction costs are affected by several variables. Design is a major item. For a given production level, hatcheries using single pass are more expensive than those with multiple use. Development of a suitable water supply is often the single most costly item. Heating and cooling of water adds substantially to hatchery operational costs. To heat or cool 1 cfs of water 1°C for 1 day, requires 9,702,143 BTU. Although energy requirements were calculated when required, mechanical temperature modification is not considered practical for the single-pass hatchery designs used in this plan.

Preliminary estimates for the capital costs of mitigation hatcheries were based on information presented in Figure 9 (Kramer, Chin

and Mayo, 1976) which relates cost to degree of complexity and rearing (and holding) volume. Capital cost includes land acquisition, design, construction, and development of the entire fish facility (water supply, power supply, adult collection system, adult holding ponds, spawning, incubation, and nursery facilities, and sewage treatment facilities), and any auxiliary facilities (residences, access roads, etc.). Operational costs were estimated from information presented in Figure 10 (Kramer, Chin and Mayo, 1976), which relates cost to annual production and release size. To update estimates to 1980 levels, Figure 9 costs were multiplied by a corporate index factor of 1.34 (Water & Power Resources Service composite construction cost index), and Figure 10 costs were multiplied by the consumer price index factor of 1.45 (U.S. Department of Commerce - Survey of Current Business).

HATCHERY I. Hatchery I (Figure 5) would have an annual production to meet 52 percent of the compensation requirement for steelhead (117,000 lbs.). At maximum capacity, it would require:

Adult holding ponds	3
Incubation trays	188
Starter troughs	6
Raceways	22

The projected cost of this facility would be $8.3 million. Monthly water requirements at maximum loading are listed in Table 3. Annual operational costs would be approximately $229,000.

HATCHERY II. The annual production at Hatchery II (Figure 6) would provide 48 percent (108,000 lbs.) of the compensation requirement for steelhead. It would require:

Adult holding ponds	3
Incubation trays	173
Starter troughs	6
Raceways	20

The projected cost would be $8.0 million. Monthly water requirements are listed in Table 4. Operational costs were estimated at $210,000 annually.

HATCHERY III. Hatchery III (Figure 7) would annually produce 50 percent of the fall Chinook requirement (29,445 lbs.), and 100 percent of the coho and spring Chinook requirements (8,291 and 10,240 lbs., respectively). It would require:

Adult holding ponds	8
Incubation trays	381
Starter troughs	13
Raceways	14

The projected cost would be $10.7 million. Monthly water requirements are listed in Table 5. Annual operational costs were estimated at $143,500.

HATCHERY IV. Annual production at Hatchery IV (Figure 8) would provide 50 percent of the fall Chinook requirement (29,445 lbs.), and 100 percent of the summer Chinook requirement (47,840 lbs.). At maximum loading it would require:

Adult holding ponds	8
Incubation trays	415
Starter troughs	14
Raceways	19

The projected cost for this facility would be $12.0 million. Monthly water requirements are listed in Table 6. Operational costs would be approximately $185,600 per year.

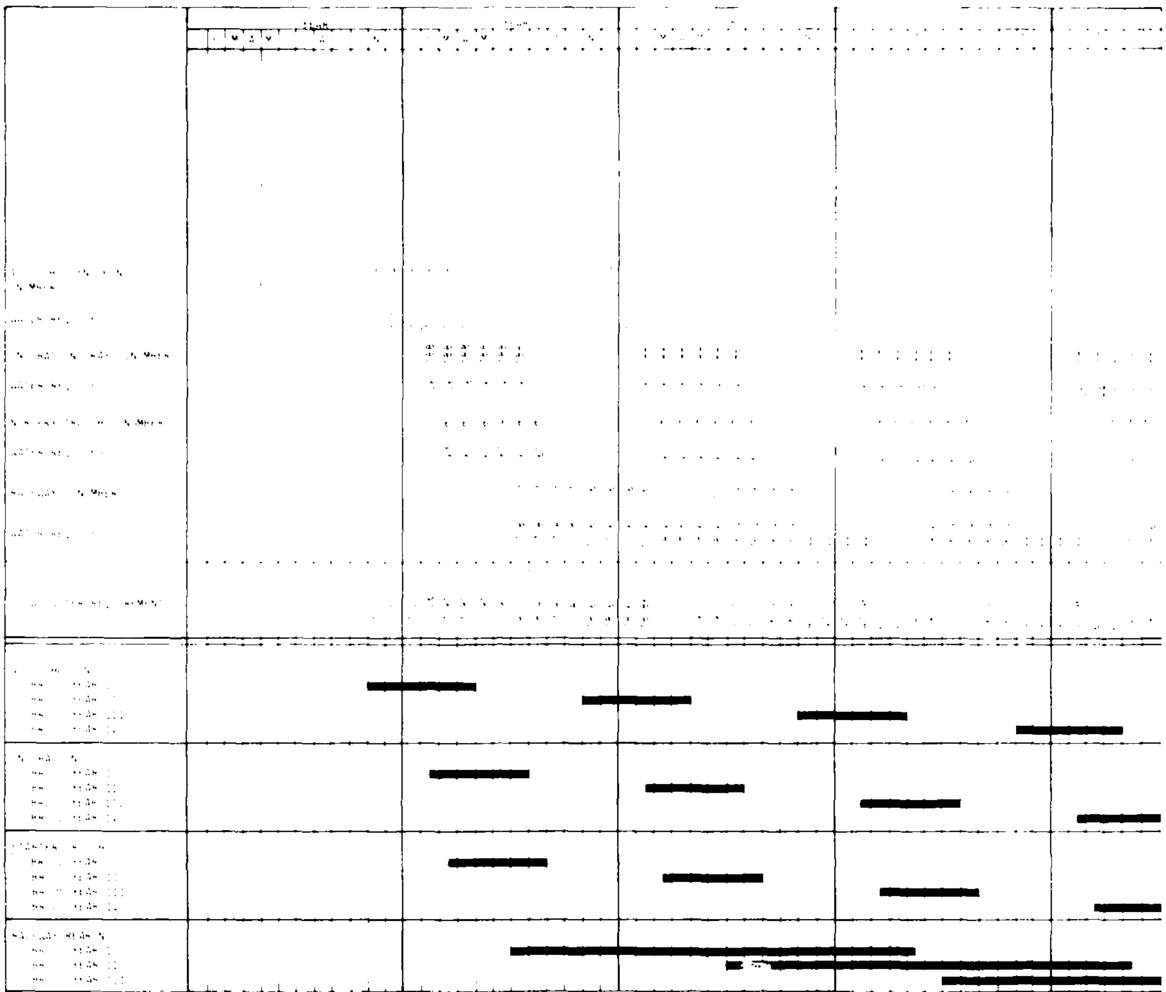


FIGURE 5 HATCHERY I 52 (11? 000 LBS) OF STEELHEAD COMPENSATION REQUIREMENT

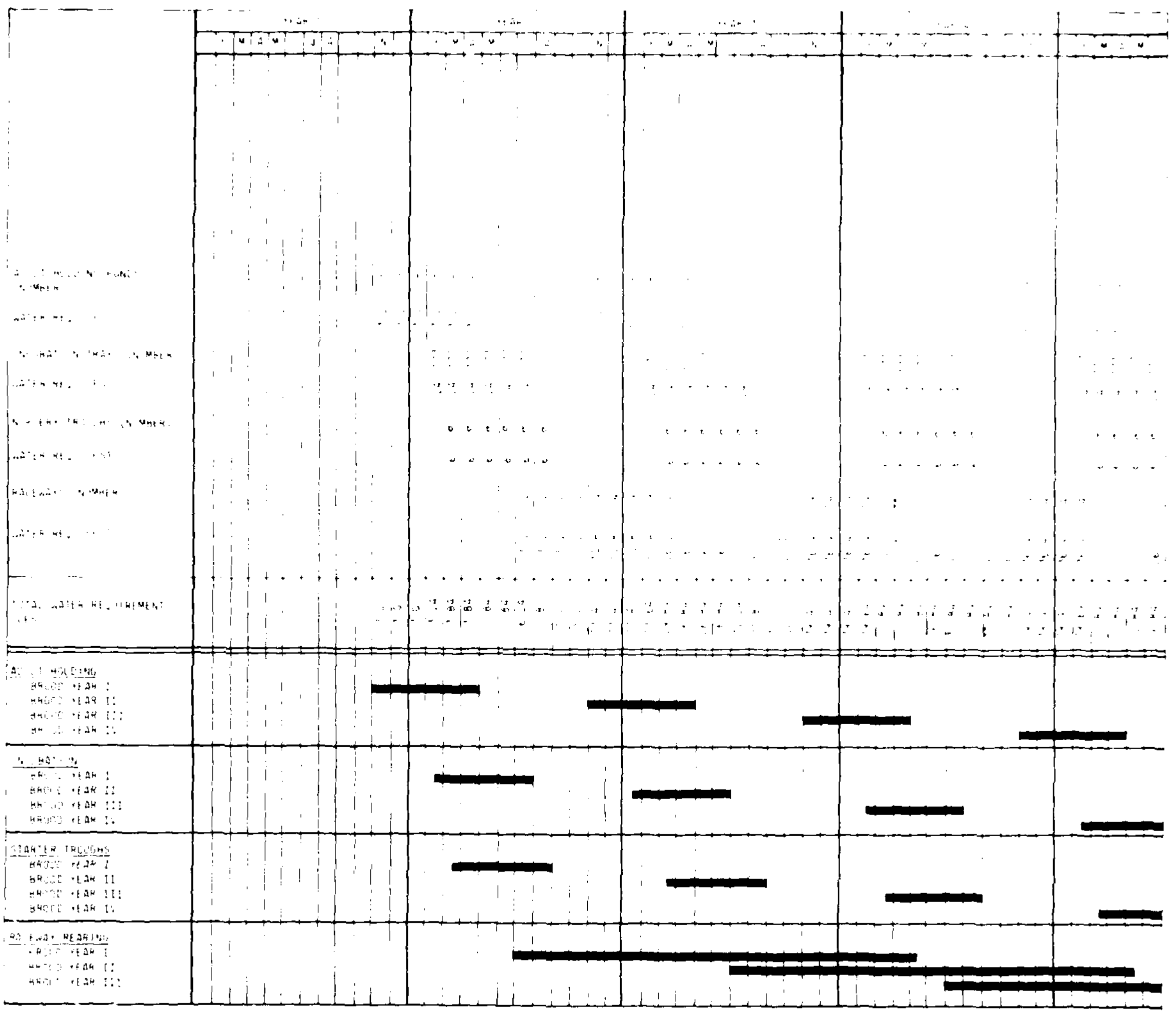


FIGURE 6 HATCHERY II 48% (108 000 LBS) OF STEELHEAD COMPENSATION REQUIREMENT

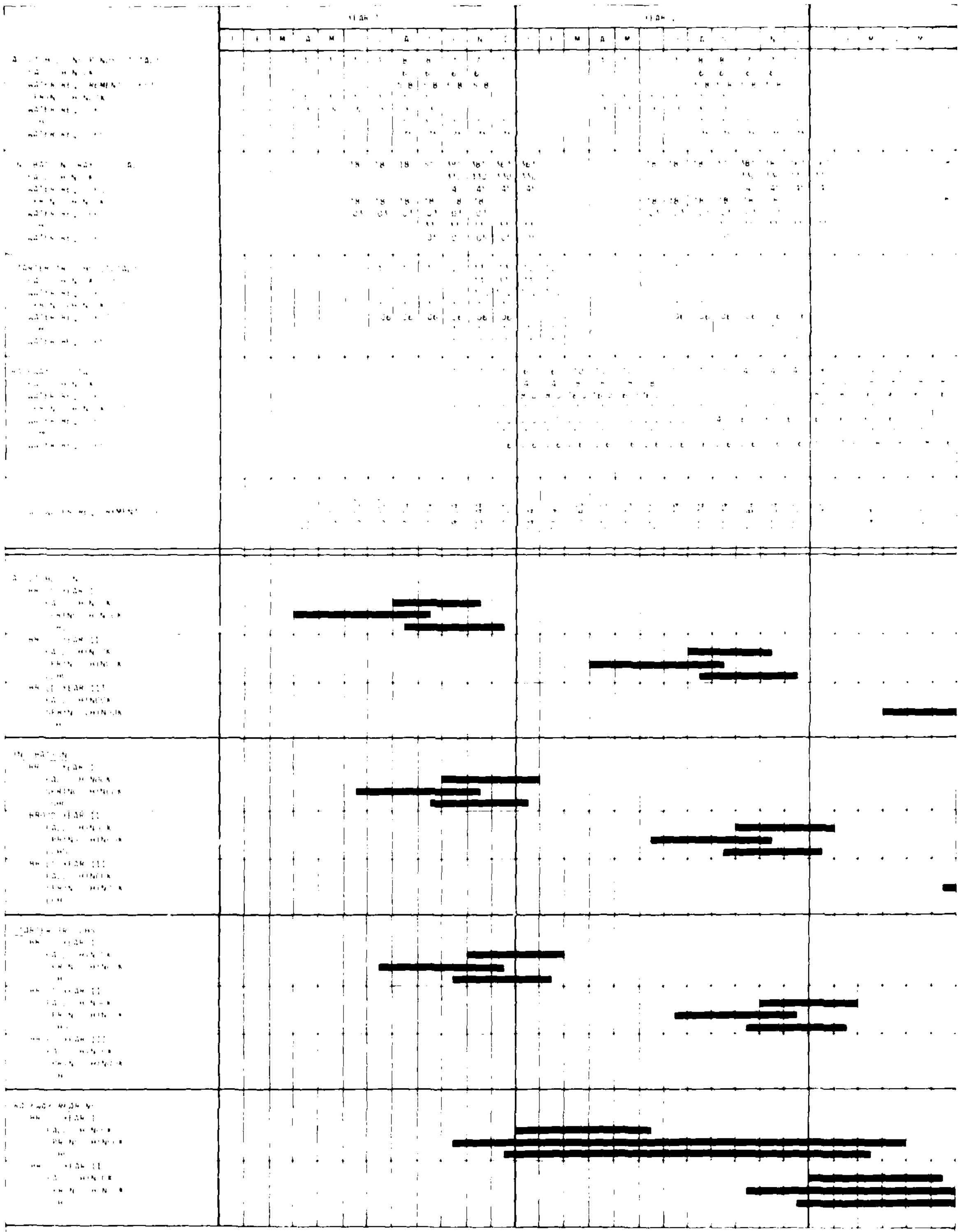


FIGURE [illegible]. HATCHERY III: 50% FALL CHINOOK REQUIREMENT (29,995 LBS), 100% COHO REQUIREMENT (8,290 LBS)
AND 100% OF SPRING CHINOOK REQUIREMENT (10,290 LBS)

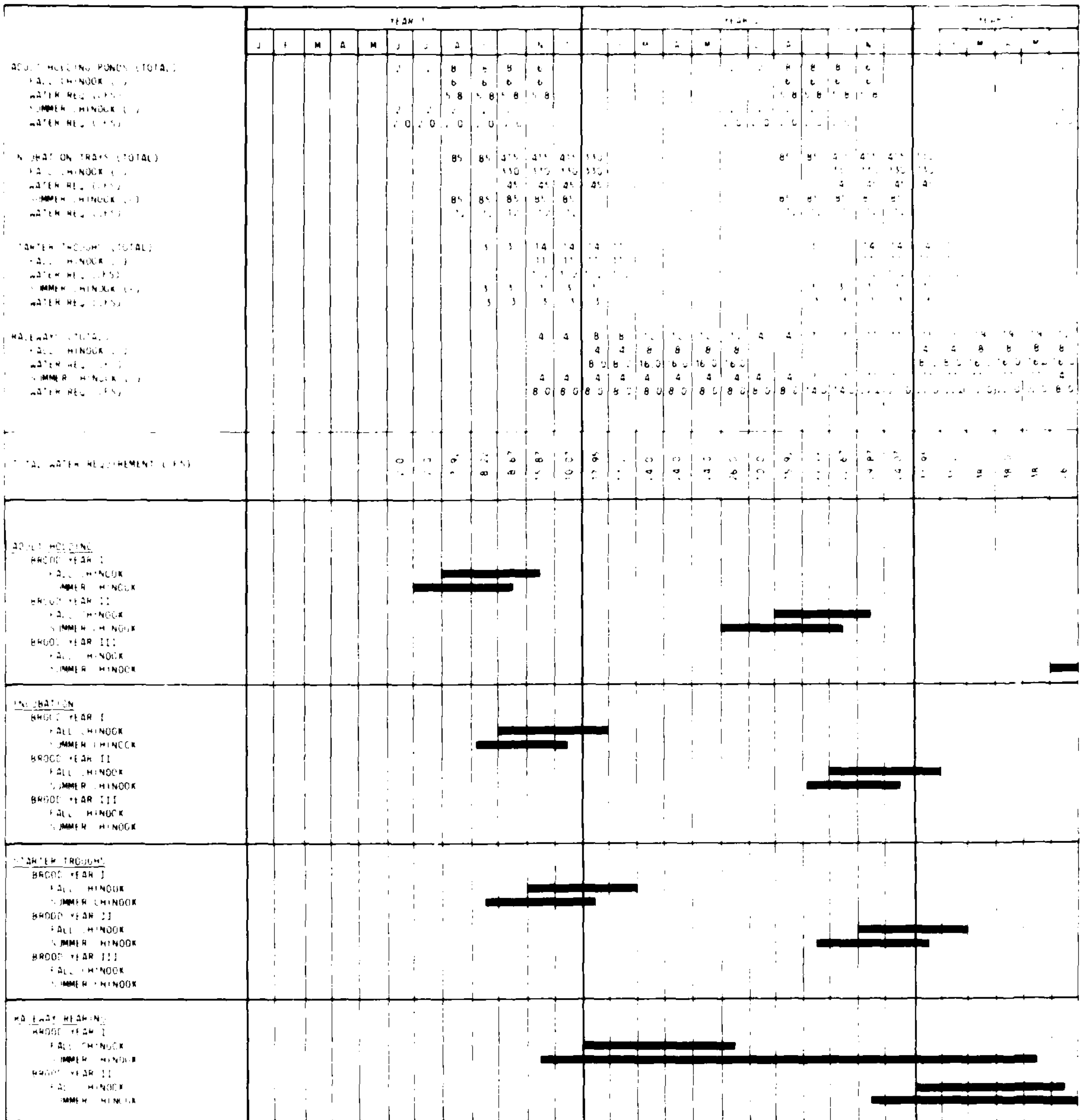


FIGURE 8. HATCHERY IV. 50% OF FALL CHINOOK REQUIREMENT ([illegible] LBS.) AND 100% OF THE SUMMER CHINOOK REQUIREMENT ([illegible] LBS.)

TABLE 3

MONTHLY WATER REQUIREMENTS (CFS)
FOR VARIOUS PRODUCTION PHASES OF HATCHERY I AT MAXIMUM LOADING

	Adult Holding (<13.3°C)	Incubation (5.5-13.3°C)	Rearing (Ambient)
January	3.0	-	44.20
February	3.0	-	44.20
March	3.0	0.26	57.20
April	3.0	0.26	57.20
May	-	0.26	57.85
June	-	0.26	29.25
July	-	0.26	37.05
August	-	0.26	37.05
September	-	-	36.4
October	-	-	36.4
November	3.0	-	44.2
December	3.0	-	44.2

TABLE 4

MONTHLY WATER REQUIREMENTS (CFS)
FOR VARIOUS PRODUCTION PHASES OF HATCHERY II AT MAXIMUM LOADING

	Adult Holding (<13.3°C)	Incubation (5.5-13.3°C)	Rearing (Ambient)
January	3.0	-	36.4
February	3.0	-	36.4
March	3.0	0.24	52.6
April	3.0	0.24	52.6
May	-	0.24	52.6
June	-	0.24	26.6
July	-	0.24	31.8
August	-	0.24	31.8
September	-	-	31.2
October	-	-	31.2
November	3.0	-	36.4
December	3.0	-	36.4

TABLE 5

MONTHLY WATER REQUIREMENTS (CFS)
FOR VARIOUS PRODUCTION PHASES OF HATCHERY III AT MAXIMUM LOADING

	Adult Holding ($<13.3^{\circ}C$)	Incubation ($5.5-13.3^{\circ}C$)	Rearing (7.2-14.4)
January	-	0.50	20.50
February	-	-	23.10
March	-	-	29.80
April	0.5	-	28.80
May	0.5	-	25.80
June	0.5	0.03	20.60
July	0.5	0.03	4.61
August	7.05	0.03	4.61
September	7.05	0.08	6.61
October	6.55	0.53	8.62
November	6.55	0.53	10.0
December	0.75	0.50	10.0

TABLE 6

MONTHLY WATER REQUIREMENTS (CFS)
FOR VARIOUS PRODUCTION PHASES OF HATCHERY IV AT MAXIMUM LOADING

	Adult Holding (<13.3^{o}C)	Incubation (5.5-13.3^{o}C)	Rearing (7.2-14.4)
January	-	0.45	31.5
February	-	-	31.2
March	-	-	38.0
April	-	-	38.0
May	-	-	38.0
June	2.0	-	38.0
July	2.0	-	8.0
August	7.8	0.12	8.0
September	7.8	0.12	14.3
October	7.8	0.57	14.3
November	5.8	0.57	23.5
December	-	0.57	23.5

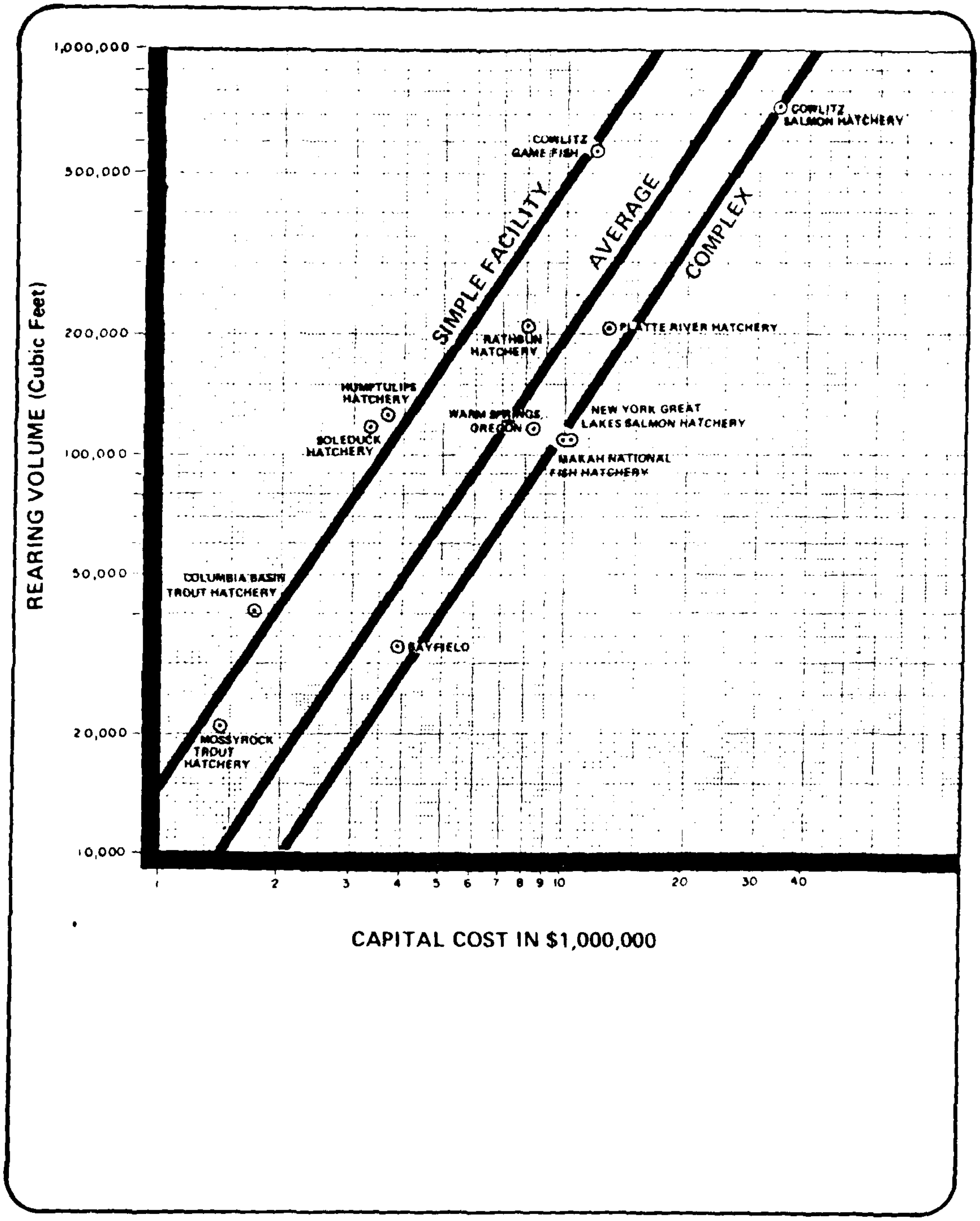


Figure 9. Estimated capital cost (in $1,000,000) related to rearing volume. (From Kramer, Chin & Mayo, 1976).

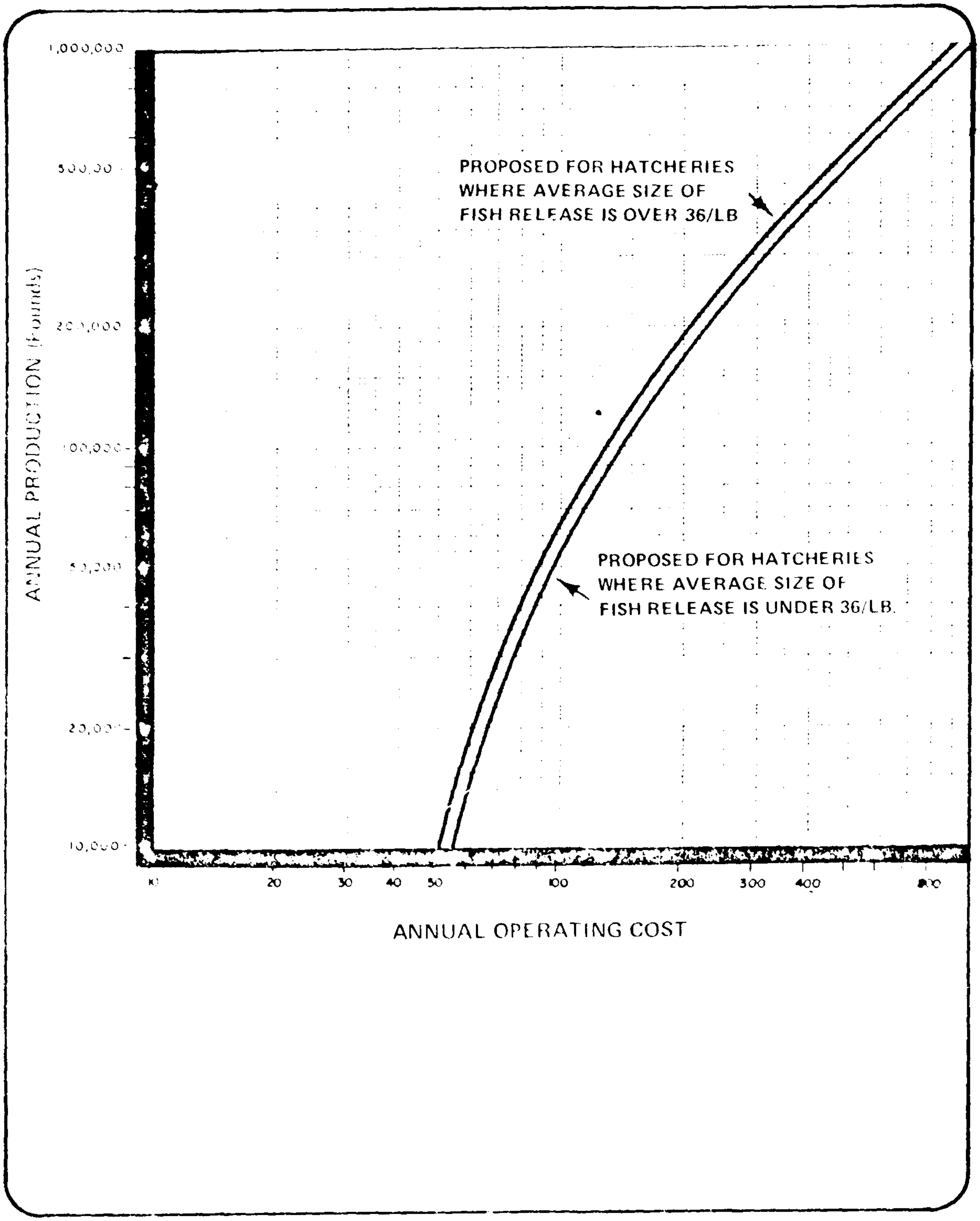


Figure 10 Estimated annual operating costs (in $1,000) related to annual production (From Kramer, Chin & Mayo, 1976)

SITE SELECTION

The mitigation goal is to site the hatchery(ies) near the Hanford Reach. Accordingly, the area of consideration for potential hatcheries was limited to the Columbia River drainage from the Columbia-Snake confluence (RM 325) to Priest Rapids Dam (RM 396). The only tributary of any consequence in this reach is the Yakima River. During the irrigation season, flow in the Yakima's lower segment is made up almost entirely of irrigation returns, and its extremely warm temperatures, low flow, and poor quality eliminate it from consideration as a hatchery water supply (Washington State Department of Ecology, 1975). The Yakima's upper reaches have flows and water quality suitable for hatchery use, but the low flows and poor quality in the lower segment are detrimental to fish passage and would restrict upstream migration of adults during late summer and early fall. The production requirement for any facility sited above Priest Rapids Dam would have to be increased to offset turbine mortalities.

The Columbia River's Hanford Reach has relatively good water quality with regard to fish cultural requirements. The major limitation to its use as a hatchery water supply is temperature. With the exception of steelhead, which can be adapted to two-year rearing at ambient temperatures, river temperatures are generally too cold in the winter and too warm in the summer for optimum production. River water could be used to supply other salmonid hatcheries during the times of the year when temperatures are within acceptable ranges. For the remainder of the year, the river supply's temperatures would have to be moderated by supplemental cooling and heating, or by mixing with a suitable groundwater supply.

The principal groundwater-bearing units in the area are the basalts of the Columbia River group, the conglomerate of the Ringold Formation, and the glaciofluviate and fluviate deposits. The water table lies

mainly in the Ringold Formation, and only locally extends into post-Ringold deposits (Newcomb et al, 1972). Although wells penetrating the basalt sequence are capable of moderate to high yields, the Ringold Formation has a much greater water bearing potential and can be developed more economically. The potential yields from this aquifer are difficult to assess, however, because of the large degree of variation in the bedrock topography and the consequent variation in the saturated thickness of the aquifer.

A study conducted in the vicinity of Priest Rapids Dam to determine the feasibility of developing groundwater for fish rearing at the Priest Rapids facility identified a productive aquifer with an estimated flow of 30-50 cfs (Hart-Crowser, 1978). The productivity of this aquifer is thought to be directly related to recharge from the reservoir upstream from the dam. Although the potential exists for withdrawing 30-50 cfs, at present only 6 cfs have been confirmed. Based on the available data, it is not possible to identify areas in the Hanford Reach where an adequate supply of groundwater could be successfully developed.

The suitability of supplying hatcheries with Columbia River water is illustrated in Figures 11, 12, and 13. As indicated in Figure 11, Hatcheries I and II, in which two-year steelhead rearing is proposed, could use ambient river water. Supplemental cooling would be required for a small amount of incubation water (maximum of 250 gpm) during June, July, and August. During the summer, disease outbreaks would be expected in these hatcheries. Production loadings, however, would be at little more than half their projected maximum at this time, and management involving timely prophylactic or therapeutic treatment could keep losses at a minimum. Hatcheries I and II could theoretically be sited any place along the river where suitable land is available.

Ambient river water would not be a suitable supply for Hatcheries III and IV (Figures 12 and 13, respectively). June through September

water temperatures would be too warm to successfully hold spring and summer Chinook spawners. Cessation of growth during sub-optimal winter temperatures would not allow any species to attain proper release sizes within their production cycle time frames.

With the surface water temperature regime in the Hanford Reach and the lack of confirmed groundwater sources, mitigation goals for spring, summer, and fall Chinook and coho could be met only if mechanical heating and cooling were employed at the hatcheries. Calculations of the energy costs involved in modifying ambient Columbia River water temperatures to supply Hatcheries III and IV (Tables 7 and 8), were based on monthly water quantity and quality requirements listed in Tables 5 and 6. It should be noted that the annual energy requirements associated with this approach, 125,000,000,000 BTU for Hatchery III, and 183,000,000,000 BTU for Hatchery IV, were calculated assuming heating and cooling efficiencies of 100 percent, and, as such, represent low estimates. Aside from assuring that they are located in areas where adequate energy could be provided, Hatcheries III and IV could be sited at any place along the river where suitable land is available.

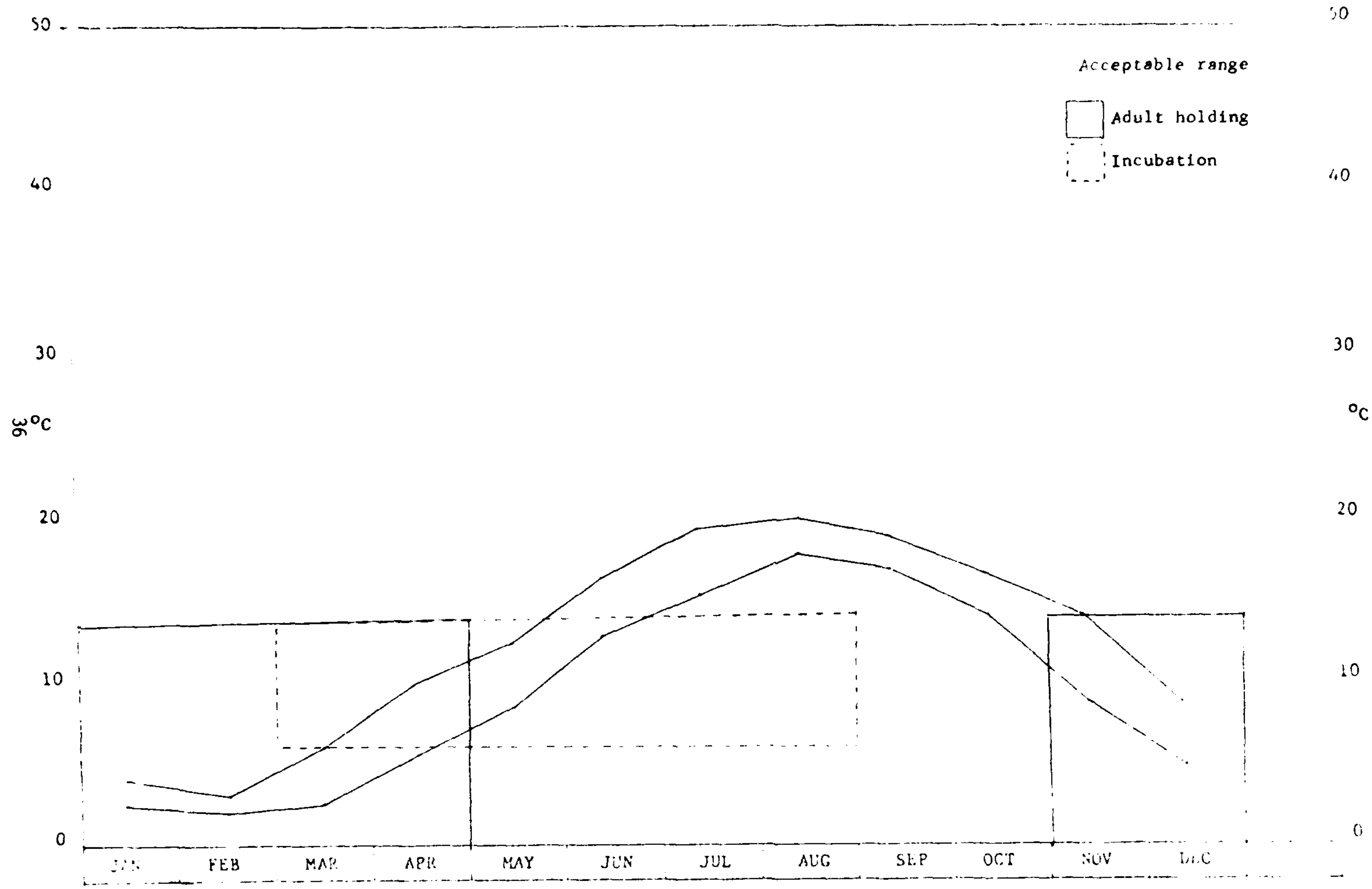


Figure 11. Average minimum and maximum water temperatures in the Hanford Reach, Columbia River, Washington, with specific temperature requirements for adult holding and egg incubation at hatcheries I and II (raceway rearing will take place at ambient temperatures).

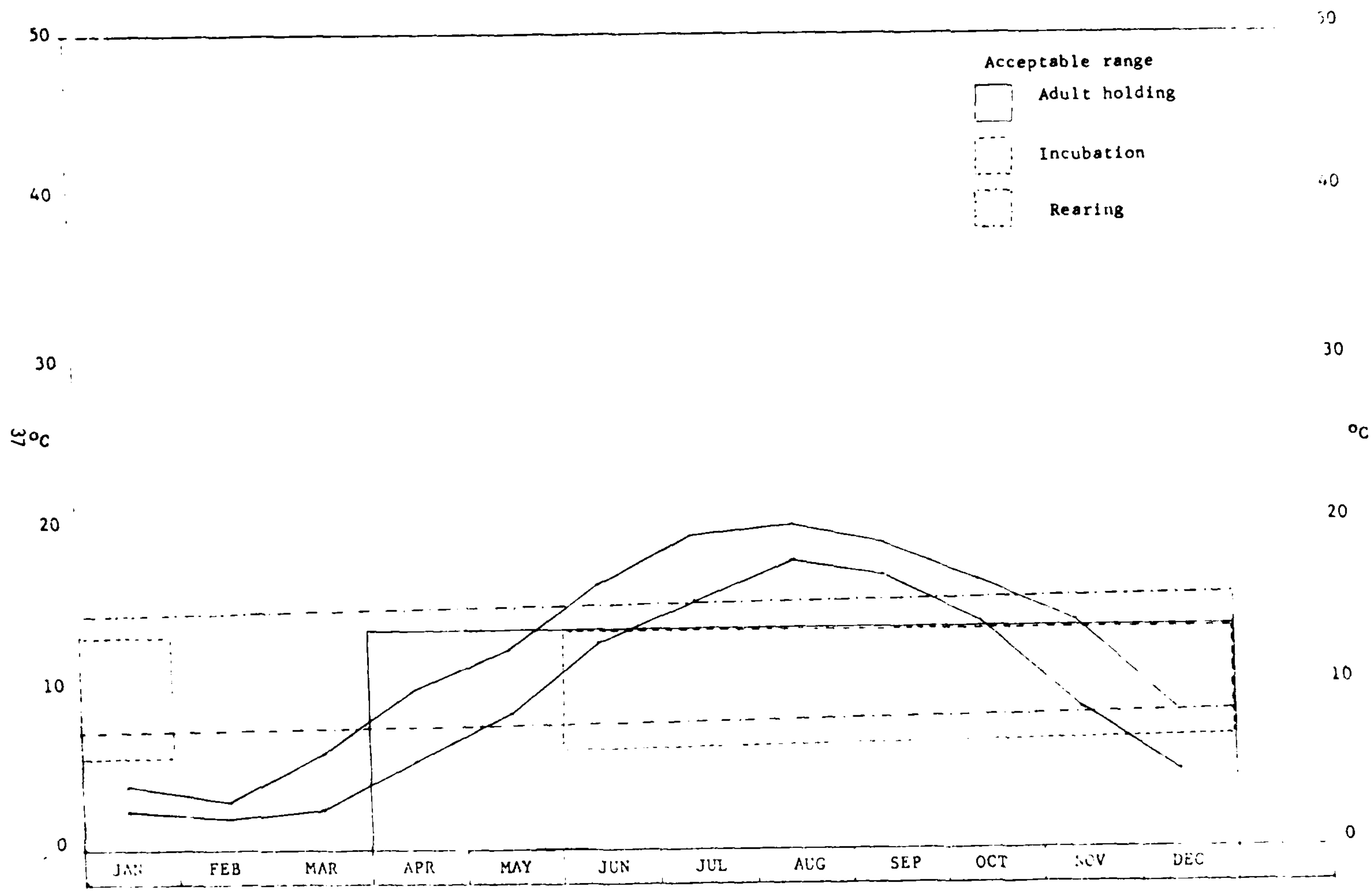


Figure 12. Average minimum and maximum water temperatures in the Hanford Reach, Columbia River, Washington, with specific temperature requirements for adult holding, egg incubation, and rearing at hatchery III.

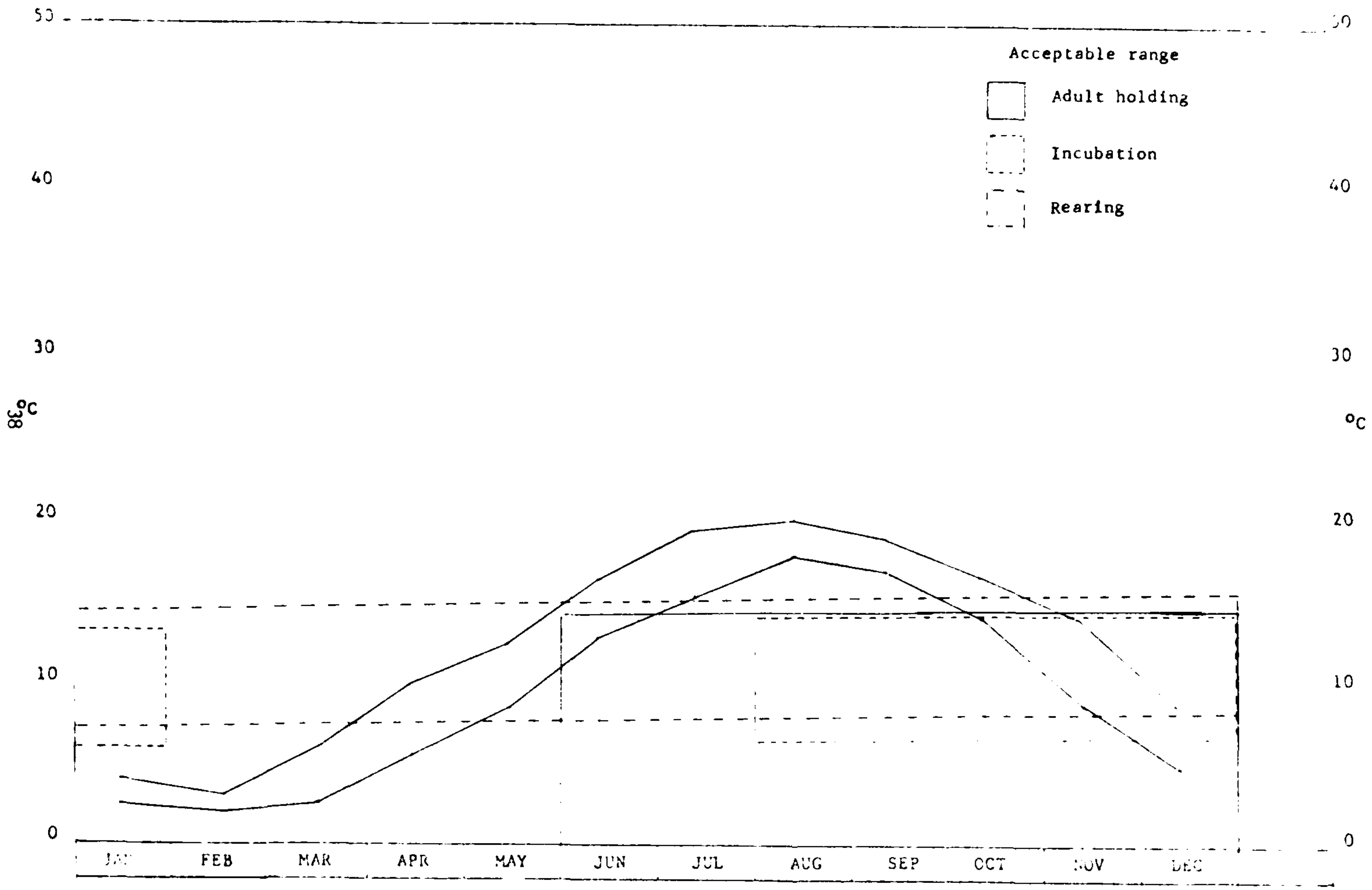


Figure 13. Average minimum and maximum r temperatures in the Hanford Reach, Columbia River, Washington, with specific temperature requirements for ad holding, egg incubation, and rearing at hatchery IV.

TABLE 7
MONTHLY ENERGY REQUIREMENTS INVOLVED IN MODIFYING AMBIENT COLUMBIA WATER TEMPERATURES TO SUPPLY HATCHERY III

Month	River temperature	Incubation (5.5 - 13.3°C)			Rearing (7.2 - 14.4°C)			Adult Holding ($<$ 13.3°C)			Total
	°C	Δ T	cfs	BTU X 10^6	Δ T	cfs	BTU X 10^6	Δ T	cfs	BTU X 10^6	BTU X 10^6
JAN	4.5	1.0	0.5	145.5	2.7	20.5	16,110.4	-	-	-	16,255.9
FEB	2.8	-	-	-	4.4	23.1	29,583.8	-	-	-	29,583.8
MAR	3.7	-	-	-	3.5	29.8	30,358.0	-	-	-	30,358.0
APR	6.9	-	-	-	0.3	28.8	2,514.8	-	0.5	-	2,514.8
MAY	10.6	-	-	-	-	25.8	-	-	0.5	-	-
JUN	14.4	1.1	0.03	9.6	-	20.6	-	1.1	0.5	160.1	169.7
JUL	18.2	4.9	0.03	42.8	3.8	4.6	5,098.9	4.9	0.5	713.1	5,854.8
AUG	18.9	5.6	0.03	48.9	4.5	4.6	6,038.1	5.6	7.0	11,491.2	17,578.2
SEP	18.7	5.4	0.08	125.7	4.3	6.6	8,272.9	5.4	7.0	11,080.8	19,479.4
OCT	15.6	2.3	0.53	354.8	1.2	8.6	3,010.8	2.3	6.5	4,384.9	7,750.4
NOV	11.6	-	0.53	-	-	10.0	-	-	6.5	-	-
DEC	7.7	-	0.50	-	-	10.0	-	-	0.8	-	-
				727.3			100,987.7			27,830.1	129,545.0

TABLE 8
MONTHLY ENERGY REQUIREMENTS INVOLVED IN MODIFYING AMBIENT
COLUMBIA WATER TEMPERATURES TO SUPPLY HATCHERY IV

Month	River temperature	Incubation (5.5 - 13.3°C)			Rearing (7.2 - 14.4°C)			Adult Holding (< 13.3°C)			Total
	°C	ΔT	cfs	BTU X 10^6	ΔT	cfs	BTU X 10^6	ΔT	cfs	BTU X 10^6	BTU X 10^6
JAN	4.5	1.0	0.45	131.0	2.7	31.5	24,755.0	-	-	-	24,886.0
FEB	2.8	-	-	-	4.4	31.2	39,957.3	-	-	-	39,957.3
MAR	3.7	-	-	-	3.5	38.0	38,711.6	-	-	-	38,711.6
APR	6.9	-	-	-	0.3	38.0	3,318.1	-	-	-	3,318.1
MAY	10.6	-	-	-	-	38.0	-	-	-	-	-
JUN	14.4	-	-	-	-	38.0	-	1.1	2.0	640.3	640.3
JUL	18.2	-	-	-	3.8	8.0	8,848.4	4.9	2.0	2,852.4	11,700.8
AUG	18.9	5.6	0.12	195.6	4.5	8.0	10,478.3	5.6	7.8	12,713.7	23,387.6
SEP	18.7	5.4	0.12	188.6	4.3	14.0	17,522.1	5.4	7.8	12,259.6	29,970.3
OCT	15.6	2.3	0.57	381.6	1.2	14.0	4,889.9	2.3	7.8	5,221.7	10,493.2
NOV	11.6	-	0.57	-	-	23.5	-		5.8	-	-
DEC	7.7	-	0.57	-	-	23.5	-		-	-	-
				896.8			148,480.7			33,687.7	183,065.2

RECOMMENDATIONS

In the Hanford Reach, where the lack of a suitable water supply is a limiting factor, hatcheries based on single water use are *not* practical. Discussions should be initiated with the appropriate agencies, and, test facilities built if necesssary, to allow incorporation of a hatchery technology more appropriate to the region (e.g. recirculation).

This study was restricted by the lack of regional groundwater information. With the energy costs required to thermally modify water, siting a hatchery in the Hanford Reach may not be possible unless a groundwater supply is located. If mitigation studies are to be continued, a preliminary groundwater investigation should be undertaken.

The area of consideration for siting new hatcheries or expanding existing ones should be extended beyond the Hanford Reach area. Although most of the suitable water sources in the Columbia Basin have already been appropriated, the majority of existing hatcheries are using "old" technology. Modification for increased production could probably accommodate a substantial portion of the mitigation requirement for the Ben Franklin Dam alternative.

GLOSSARY

Because this Report is designed for use by individuals with varying degrees of exposure to Fisheries Science and its vocabulary, a brief definition of terms frequently used throughout the text follows:

Adult Holding Pond - Any pond or raceway used to hold and sort salmon until they are spawned.

Artificial Propagation - The spawning, hatching and rearing of fish under controlled conditions for future release into "natural" environments.

Carrying Capacity - Weight of fish reared per unit flow (usually expressed as pounds/gpm).

Fry - As used in ths study, the stage in a fish's life from hatching (sac fry) until it reaches approximately one inch in length.

Loading Density - Weight of fish reared per unit volume, usually expressed in pounds/cf.

Natural Production - Fish that are spawned, hatched, and reared without human intervention, i.e., in a natural stream environment.

Raceway - A fish propagation unit constructed of concrete or similar durable, non-porous material that receives a continuous flow of water. A raceway generally ranges between 500 and 10,000 cf in volume and has a linear flow. Raceways may be recessed or constructed above ground level.

Smolt - A fish which has passed through the physiological process of becoming ready to migrate to saltwater.

Start Tank - A small fish propagation unit constructed of a non-porous material which is generally used to rear fish in the fry stage providing a suitable environment for them to start feeding. Start tanks are usually less than 200 cf in volume, found in or near the hatchery building, and may be above ground level or slightly recessed.

REFERENCES CITED

Allen, R.L. 1977. Status of the Columbia River Salmon and Steelhead Runs. IN: Columbia River Salmon and Steelhead, Ernest Schwiebert (ed.) Am. Fish. Soc. Spec. Pub. No. 10.

American Society of Heating, Refrigerating, and Air-Conditioning Engineers, Inc. 1961. ASHRAE Guide and Data Book - Fundamentals and Equipment. New York, New York.

Bell, M.C. 1973. Fisheries Handbook of Engineering Requirements and Criteria, Fisheries Engineering Research Program, U.S. Army Corps of Engineers, North Pacific Division, Portland, Oregon.

Brett, J.R., Hollands, M., and D.F. Alderdice. 1958. The Effect of Temperature on the Cruising Speed of Young Sockeye and Coho Salmon, J. Fish Res. Bd., Canada, 15:4,587.

Columbia Basin Fisheries Technical Committee, Lower Snake Hatchery Subcommittee. 1974. Memorandum to COL Nelson P. Conover, Corps of Engineers, Walla Walla District. IN: Design Memorandum No. 1, Fish Facilities Site Selection Report, U.S. Army Engineers District, Walla Walla, 1977.

Fickeisen, D.H., Dauble, D.D., Neitzel, D.A., Rickard, W.H., Skaggs, R.L., and J.L. Warren. 1980. Aquatic and Riparian Resource Study of the Hanford Reach, Columbia River, Washington, prepared by Battelle Pacific Northwest Laboratories for U.S. Army Corps of Engineers, Seattle District.

Hart-Crowser & Associates, Inc. 1978. Groundwater Development for the Proposed Hatchery Facility at Priest Rapids Dam, Grant County, Washington, Seattle, Washington.

REFERENCES CITED (Continued)

Kaczynski, V.W., and D. W. Moos. 1979. Strategies for Mid-Columbia Fish Production. pp. 289-295. IN: The Mitigation Symposium: A National Workshop on Mitigating Losses of Fish and Wildlife Habitats. July 16 - 20, 1979. Colorado State University, Fort Collins, Colorado.

Klontz, G.W., Downy, P.C., and R.L. Focht. 1979. A Manual for Trout and Salmon Production, Idaho Water Resource Research Institute, University of Idaho, Moscow.

Kramer, Chin & Mayo, Inc. 1976. Washington Salmon Study. Prepared for the Washington Department of Fisheries. Seattle, Washington.

Mayo, R.D. 1980. Recirculation Systems in Northern America. Paper presented at the European Inland Fisheries Advisory Commission, Symposium on New Development in the Utilization of Heated Effluents and of Recirculation Systems for Intensive Aquaculture. Stavangar, Norway, 28 - 30 May 1980.

Newcomb, R.C., Strand, J.R., and F.J. Frank. 1972. Geology and Ground-water Characteristics of the Hanford Reservation of the U.S. Atomic Energy Commission, Washington, Geological Survey Professional Paper 717, U.S. Geological Survey.

Olsen, P.A. and R. F. Foster. 1957. Temperature Tolerance of Eggs and Young of Columbia River Chinook Salmon, Trans. Am. Fish Soc. 85,203.

Piper, R.G. 1970. Know the Proper Carrying Capacities of your Farm. Amer. Fishes and U.S. Trout News, 15(1):4, IN: A Manual for Trout and Salmon Production. G.W. Klontz, P.C. Downey, and R.L. Focht, University of Idaho, Moscow, Idaho.

Piper, R.G. 1972. Managing Hatcheries by the Numbers, Amer. Fishes and U.S. Trout News, 17(3)=10. IN: A Manual for Trout and Salmon Production. G.W. Klontz, P.C. Downey, and R.L. Focht, University of Idaho, Moscow.

U.S. Army Corps of Engineers, 1980a. Design Memorandum No. 4, Lyons Ferry, Washington, Fish Hatchery. U.S. Army Engineers District Walla Walla.

U.S. Army Corps of Engineers. 1980b. Design Memorandum No. 7, Hagerman National Fish Hatchery Expansion, U.S. Army Engineers District, Walla Walla.

Wahle, R.J. and R.Z. Smith. 1979. A Historical and Descriptive Account of Pacific Coast Anadromous Salmonoid Rearing Facilities and a Summary of Their Releases by Region, 1960-76. U.S. Dept. of Commerce NOAA-NMFS. U.S. Govt. Printing Office, Washington DC.

Washington State Department of Ecology. 1975. Characteristics of Present Water Quality Conditions in the Yakima Basin, Water Resources Information System Tech. Bull. No. 10, Olympia, Washington.

Washington State Department of Fisheries. 1980 (June) Personal Communication from Mr. R. L. Allen, Olympia, Washington.

Westgard, R.W. Washington State Dept. of Fisheries. 1977. Memorandum to CPT. Don Holzwarth, Corps of Engineers, Walla Walla District.

Wood, J.W. 1974. Diseases of Pacific Salmon, Their Prevention and Treatment, State of Washington, Department of Fisheries, 82 pp.

DA

FILM

03-